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RESEARCH NOTES

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Western Australian Department of Agriculture

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INSTRUCTIONS TO AUTHORS

1. Papers dealing with flora and vegetation of Western Australia will be considered for publication.

2. Style should follow that of a recent issue. All *instructions*, including drawings, maps, graphs, and photographs, should follow a single, numbered sequence in each paper. They should be submitted in their final size for printing (maximum dimensions 15 cm x 24 cm including space for caption). *References* should quote titles of periodicals in full. Authors should suggest a *short title* for page headings.

3. Papers will be reviewed by an editorial committee. Contributions should be addressed to The Editor, Research Notes, Western Australian Herbarium, Department of Agriculture, George Street, South Perth, Western Australia 6151.

4. VOUCHER SPECIMENS: It is suggested that botanical names central to the objective of the paper be supported by specimens deposited in a recognized herbarium and that the institution be cited in the paper. It is desirable to quote, in the paper, numbers identifying specimens whose determination is uncertain. An explanatory note on the subject is available from the Editor.

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WESTERN AUSTRALIAN HERBARIUM RESEARCH NOTES

No. 9, 1983: 1-13

A BOTANICAL SURVEY OF A RABBIT STUDY AREA, CAPE NATURALISTE

By T.E.H. Aplin[1], L. Rhodes[2] and D.R. King[2]

1. Western Australian Herbarium, Department of Agriculture, Jarrah Road, South Perth, W.A. 6151.
2. Research Section, Agriculture Protection Board of Western Australia, Bougainvillea Avenue, Forrestfield, W.A. 6058.

ABSTRACT

Five plant communities were recognised within a Rabbit Study Area of about 275 ha at Cape Naturaliste, Western Australia. 235 plant species were recorded, of which 176 were native to the area and 59 were introduced aliens.

The vegetation and flora of the area were typical of those present on coastal calcareous soils, under similar conditions of clearing and disturbance.

INTRODUCTION

The Rabbit Study Area (RSA) at Cape Naturaliste was at the time of the botanical survey being used by the Research Section of the Agriculture Protection Board for studying the biology and control of rabbit populations. The RSA lies approximately 5 km south-south-east of Cape Naturaliste lighthouse (33°34'S, 115°02'E), with the town of Busselton lying approximately 33 km to the south-east.

The RSA comprises parts of Sussex locations 1046 and 725 and is that area in these locations that had been cleared of native vegetation and converted to pasture, together with uncleared vegetation surrounding the cleared area to a distance of 20 m. The area of the RSA is approximately 275 ha.

The climate experienced is a mediterranean type with a mean annual rainfall of 838 mm and the wettest six-monthly period of the year from May to October. The maximum temperature means are 25.8°C in February and 16.2°C in July, with the minimum temperature means for the same months being 15.8°C and 10.2°C respectively. Climatic records are from the Cape Naturaliste lighthouse station (Table 1).

The soils of the RSA are calcareous sands overlying limestone which outcrops in small localised patches. The topography is undulating with the highest point about 200 m above sea level.

Table 1. Mean maximum and minimum temperatures and mean monthly rainfall recorded at Cape Naturaliste Lighthouse 30°32'S, 115°1'E, elevation 111.9 m (courtesy Department of Science and Technology, Bureau of Meteorology, Perth).

	Daily Maximum Temperature °C Mean	Daily Minimum Temperature °C Mean	Rainfall mm Mean
JAN	25.4	15.4	10
FEB	25.8	15.8	12
MAR	24.1	14.8	25
APR	21.0	13.4	47
MAY	19.1	12.6	119
JUN	17.2	11.4	117
JUL	16.2	10.2	167
AUG	16.2	9.8	115
SEP	16.9	9.9	75
OCT	18.7	10.8	54
NOV	21.0	12.2	23
DEC	23.8	14.1	14
		ANNUAL TOTAL	838

The area has, and was at the time of the survey, been utilized by the property owner, Mr. J. D'Espeissis, for grazing cattle. The other main herbivore found in the area is the Western grey kangaroo, *Macropus fuliginosus ocydromus*.

The botanical survey was conducted to provide base data for determining the habitat, and food preferences, of rabbits.

METHOD

The plant communities in the RSA were mapped by aerial photographic interpretation, supported by data obtained from ground traverses. The structural classification used follows that adopted by Aplin (1981).

Several locations in each of the vegetation communities were sampled floristically to provide a flora list of the area. Nomenclature follows Green (1981), and voucher specimens have been lodged at the Western Australian Herbarium (PERTH).

The composition of the herbland (pasture) vegetation was determined using the Point Quadrat method, along 8 transects, each about 100 m long. Points were set 1 m apart.

RESULTS

Five plant communities were recognised in the RSA and their distributions mapped on an aerial photograph (Fig. 1). They are:

1. Low woodland, consisting of *Agonis flexuosa* and, in localized areas, *Eucalyptus calophylla* (Fig. 2).
2. Open scrub of *Acacia rostellifera* (Fig. 3).
3. High shrubland, consisting of *Dryandra sessilis* on exposed limestone and *Agonis flexuosa* on shallow soils (Fig. 4).
4. Open heath of a mixture of species with emergent *Xanthorrhoea preissii*, usually found on high ground (Fig. 5).
5. Herbland, or annual pasture, consisting of species of naturalised alien plants (Fig. 6).

The species composition of herbland, measured over three consecutive years, are provided in Table 2.

Table 2. Percentage cover of species in the mixed herbland community.

Species	Percentage cover		
	1978	1979	1981
Arctotheca calendula	25.0	18.6	10.9
Lolium rigidum	22.4	37.8	58.9
Medicago polymorpha	16.8	-	0.8
Trifolium subterraneum	12.7	7.9	3.0
Hypochoeris glabra	9.4	4.2	2.6
Erodium botrys	7.2	9.5	10.6
Hordeum leporinum	2.9	-	-
Bromus diandrus	1.1	5.9	2.3
**Orobanche australiana*	1.1	0.3	0.1
Bromus hordeaceus	0.5	6.1	5.4
Aira caryophyllea	0.4	-	-
Trifolium glomeratum	0.4	-	-
Trifolium campestre	0.2	2.1	1.9
Polycarpon tetraphyllum	-	4.4	0.9
Vulpia bromoides	-	2.9	2.6
Ornithopus compressus	-	0.1	-
Romulea rosea	-	0.1	-
Bromus madritensis	-	-	0.1

* Native species. The rest are naturalised aliens.

235 plant species were recorded, in the RSA, of which 176 were native and 59 naturalised aliens (Appendix 1).

Most species were recorded in more than one plant community. Genera with the greatest number of species were *Hibbertia* and *Acacia* (5 species each), *Drosera*, *Lomandra* and *Stylidium* (4 each). Families with the greatest representation of species were Asteraceae, Leguminosae, Liliaceae, Orchidaceae and Poaceae.

177 of the plant species recorded in the RSA were herbaceous annuals or short-lived perennials, with only 58 woody perennial species present, the

latter belonging to families such as Casuarinaceae, Leguminosae, Myrtaceae, Proteaceae, Rutaceae and Thymelaeaceae.

DISCUSSION

The plant communities, and the plant species, recorded in the RSA are typically seen on coastal calcareous sands, overlying limestone, in south-western Australia (Smith 1974; Fox *et al.* 1980; Beard 1981), while the high proportion (25%) of naturalised alien species reflects the considerable disturbance that had taken place in the herbland, and in adjacent woodland, scrub, shrubland and heath.

In a study at Yalgorup National Park, Fox *et al.* (1980) recorded 295 species, including 51 naturalised aliens (17%), in similar plant communities and soil types, but over a much larger area (ca. 11,000 ha). 141 of these species, including 30 naturalised aliens, occur in the RSA.

The botanical survey indicated that a large proportion of plants, native and naturalised aliens, are probably important in the diet of rabbits.

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APPENDIX I

List of plant species

Families genera and species are arranged alphabetically. The site record numbers refer to plant communities as follows:

1. *Agonis flexuosa* low woodland.
2. *Acacia rostellifera* open scrub.
3. *Dryandra sessilis-Agonis flexuosa* high shrubland.
4. *Xanthorrhoea preissii* open heath.
5. Annual pasture herbland.

	Site record				
	1	2	3	4	5
Amaranthaceae					
Ptilotus drummondii (Moq.) F. Muell.	+		+	+	
Ptilotus stirlingii (Lindl.) F. Muell.			+	+	
Apiaceae					
Apium annuum P.S. Short			+		
Daucus glochidiatus (Labill.) Fisch.		+	+	+	
Eryngium pinnatifidum Bunge	+	+	+	+	
Homalosciadium homalocarpum (F. Muell.) Hj. Eichler				+	
Hydrocotyle callicarpa Bunge		+			
Hydrocotyle diantha DC.	+				
Hydrocotyle tetragonocarpa Bunge	+				
Trachymene pilosa Sm.	+	+	+	+	
Xanthosia candida Benth.		+	+	+	
Araceae					
*Zantesdeschia aethiopica (L.) Spreng	+	+	+	+	+
Asteraceae					
*Arctotheca calendula (L.) Levyns	+	+	+	+	+
Athrixia pulverulenta (Lindl.) Druce			+	+	
Brachycome goniocarpa Sonder & F. Muell. ex Sonder				+	
Brachycome iberidifolia Benth.		+	+		
*Carduus tenuiflorus W. Curtis				+	
Cotula australis (Sieb. ex Spreng.) J.D. Hooker				+	
Cotula turbinata L.	+				
Craspedia uniflora G. Forster		+	+	+	
Helichrysum filifolium (Turcz.) F. Muell.	+	+	+	+	
Helipterum cotula (Benth.) DC.		+			
*Hypochoeris glabra L.	+	+	+	+	+
Lagenifera huegelii Benth.	+	+	+	+	
Leptorhynchos elongatus DC.		+			
Millotia tenuifolia Cass.	+	+	+	+	
Olearia axillaris (DC.) F. Muell. ex Benth.	+	+			
Podolepis lessonii (Cass.) Benth.				+	
Podotheca angustifolia Less.		+	+		
Senecio lautus G. Forster ex Willd.			+	+	
*Sonchus oleraceus L.	+	+	+	+	
Waitzia citrina (Benth.) Steetz	+		+		
Brassicaceae					
*Brassica tournefortii Gouan		+			
*Heliophila pusilla L.F.	+	+		+	
*Raphanus raphanistrum L.		+			
Stenopetalum robustum Endl.		+			
Caryophyllaceae					
*Cerastium glomeratum Thuill.	+	+	+	+	
*Petrorhagia nanteuilii (Burnat) P.W. Ball & V.H. Heywood	+	+	+	+	
*Polycarpon tetraphyllum (L.) L.				+	+
*Silene gallica L.			+	+	
*Stellaria media (L.) Vill.	+	+		+	
Casuarinaceae					
Casuarina humilis Otto and Dietr.	+		+	+	
Centrolepidaceae					
Aphelia drummondii (Hieron.) Benth.	+				
Chenopodiaceae					
Rhagodia baccata (Labill.) Moq.		+	+	+	
Crassulaceae					
Crassula colorata (Nees) Ostenf.	+	+	+	+	

	Site record				
	1	2	3	4	5
Crassula pedicellosa (F. Muell.) Ostenf.	+	+		+	
Cyperaceae					
Carex inversa R.Br.			+		
Lepidosperma angustatum R.Br.		+			
Lepidosperma gladiatum Labill.	+		+		
Lepidosperma longitudinale Labill.				+	
Lepidosperma pubisquameum Steud.				+	
Schoenus curvifolius (R.Br.) Benth.				+	
Schoenus grandiflorus (Nees) F. Muell.				+	
Scirpus marginatus Thunb.	+				
Scirpus nodosus Rottb.				+	
Dilleniaceae					
Hibbertia cuneiformis (Labill.) Sm.	+	+	+	+	
Hibbertia cunninghamii W.T. Aiton	+		+	+	
Hibbertia grossulariaefolia (Salisb.) Salisb.	+		+	+	
Hibbertia hypericoides (DC.) Benth.			+	+	
Hibbertia racemosa (Endl.) Gilg.	+	+	+	+	
Droseraceae					
Drosera erythrorhiza Lindl.			+	+	
Drosera glanduligera Lehm.	+				
Drosera pallida Lindl.	+	+	+	+	
Drosera stricticaulis (Diels) O.H. Sargent	+	+	+		
Epacridaceae					
Leucopogon parviflorus (Andr.) Lindl.	+	+	+	+	
Euphorbiaceae					
*Euphorbia peplus L.	+	+	+	+	
*Euphorbia terracina L.	+				
Phyllanthus calycinus Labill.	+	+	+	+	
Phyllanthus crassifolius F. Muell.			+		
Poranthera microphylla Brongn.	+		+		
Fumariaceae					
*Fumaria officinalis L.	+				
Gentianaceae					
*Centaurium erythraea Rafn.				+	
Geraniaceae					
*Erodium botrys (Cav.) Bertol.	+			+	+
*Erodium cicutarium (L.) L'Herit.				+	+
*Erodium moschatum (L.) L'Herit.	+			+	+
*Geranium molle L.	+	+	+	+	
Geranium solanderi Carolin	+	+	+	+	
*Pelargonium capitatum (L.) L'Herit.	+			+	
Pelargonium littorale Huegel				+	
Haemodoraceae					
Anigozanthus manglesii D. Don	+	+	+	+	
Conostylis aculeata R.Br.				+	
Iridaceae					
Orthrosanthus laxus (Endl.) Benth.			+	+	
Patersonia occidentalis R.Br.		+	+	+	
*Romulea rosea (L.) Eckl.				+	+
*Sparaxis grandiflora (Delaroche) Ker-Gawl.			+	+	
Juncaceae					
Juncus pallidus R.Br.			+		
Luzula meridionalis Nordensk			+	+	
Juncaginaceae					
Triglochin calcitrapa Hooker		+			

	Site record				
	1	2	3	4	5
Triglochin tricophora Nees ex Endl.		+		+	
Lauraceae					
Cassytha nodiflora Meisn.		+			
Cassytha racemosa Nees.		+	+	+	
Leguminosae - subfamily Mimosideae					
Acacia cochlearis (Labill.) H.L. Wendl.	+	+	+	+	
Acacia littorea Maslin	+	+	+	+	
Acacia pulchella R.Br.	+	+	+	+	
Acacia rostellifera Benth.		+	+	+	
Acacia saligna (Labill.) H.L. Wendl.	+				
Leguminosae - subfamily Papilionoideae					
Bossiaea eriocarpa Benth.	+	+	+	+	
Bossiaea linophylla R.Br.	+		+	+	
Chorizema diversifolium DC.	+	+	+	+	
Chorizema ilicifolium Labill.		+	+		
Daviesia divaricata Benth.	+	+	+	+	
Gompholobium polymorphum R.Br.				+	
Gompholobium tomentosum Labill.	+	+	+	+	
Hardenbergia comptoniana (Andr.) Benth.	+		+	+	
Hovea chorizemifolia (Sweet) DC.	+		+	+	
Isotropis cuneifolia (Sm.) Benth.			+		
Jacksonia furcellata (Bonpl.) DC.	+	+	+	+	
Jacksonia horrida DC.			+	+	
Kennedia prostrata R.Br.	+	+	+	+	
*Lotus subbiflorus Lag.	+				
*Lupinus cosentinii Guss.	+		+	+	
*Medicago polymorpha L.		+			+
*Melilotus indica (L.) All.		+	+	+	
*Ornithopus compressus L.		+			+
Tempoletonia retusa (Vent.) R.Br.		+			
*Trifolium campestre Schreber	+	+	+	+	+
*Trifolium glomeratum L.				+	+
*Trifolium subterraneum L.	+	+	+	+	+
*Vicia sativa L.			+		
Liliaceae					
Acanthocarpus preissii Lehm.		+	+		
Bulbine semibarbata (R.Br.) Haw.	+	+		+	
Burchardia umbellata R.Br.	+	+	+	+	
Chamaescilla corymbosa (R.Br.) F. Muell. ex Benth.	+	+	+	+	
Lomandra caespitosa (Benth.) Ewart			+		
Lomandra endlicheri (F. Muell.) Ewart			+		
Lomandra pauciflora (R.Br.) Ewart				+	
Lomandra preissii (Endl.) Ewart	+				
Sowerbaea laxiflora Lindl.	+	+	+	+	
Stypandra grandilfora Lindl.	+	+	+	+	
Thysanotus arenarius N.H. Brittan				+	
Thysanotus multiflorus R.Br.				+	
Thysanotus patersonii R.Br.	+	+	+	+	
Tricoryne elatior R.Br.		+	+	+	
Wurmbea dioica (R.Br.) F. Muell.	+			+	
Xanthorrhoea preissii Endl.	+	+	+	+	
Lobeliaceae					
Isotoma hypocrateriformis (R.Br.) Druce	+			+	
Lobelia rhytidosperma Benth.				+	
Lobelia tenuior R.Br.		+	+	+	

	Site record				
	1	2	3	4	5
Loganiaceae					
Logania serpyllifolia R.Br.	+	+	+	+	
Mitrasacme paradoxa R.Br.	+				
Myrtaceae					
Agonis flexuosa (Spreng.) Schauer	+	+	+	+	
Calothamnus sanguineus Labill.				+	
Eucalyptus calophylla Lindl.	+				
Eucalyptus marginata Donn ex Sm.	+				
Hypocalymma robustum Endl.	+	+	+	+	
Melaleuca acerosa Schauer	+	+	+	+	
Melaleuca huegelii Endl.	+	+		+	
Orchidaceae					
Caladenia flava R.Br.	+	+	+	+	
Caladenia huegelii H. Reichenb.		+	+	+	
Caladenia latifolia R.Br.	+	+	+	+	
Diuris longifolia R.Br.	+	+	+	+	
Elythranthera brunonis (Endl.) George	+				
Eriochilus dilatatus Lindl.				+	
Pterostylis nana R.Br.			+		
Pterostylis scabra Lindl.				+	
Pterostylis vittata Lindl.			+		
Thelymitra villosa Lindl.				+	
Orobanchaceae					
Orobanche australiana F. Muell.		+	+	+	+
Oxalidaceae					
Oxalis corniculata L.	+		+	+	
Pittosporaceae					
Billardiera candida (Endl.) E.M. Bennett		+	+	+	
Billardiera erubescens (Putterl.) E.M. Bennett		+			
Plantaginaceae					
Plantago debilis R.Br.				+	
Poaceae					
*Aira caryophyllea L.	+	+	+	+	+
*Avellinia michelii (Savi) Parl		+			
*Avena barbata Link	+	+	+	+	
*Briza maxima L.	+	+	+	+	
*Briza minor L.	+	+	+	+	
*Bromus diandrus Roth			+	+	+
*Bromus hordeaceus L.			+	+	+
*Bromus madritensis L.		+			+
Danthonia caespitosa Gaud.			+	+	
Dichelachne crinita (L.F.) J.D. Hooker			+	+	
*Ehrharta longiflora Sm.	+	+	+		
*Hordeum leporinum Link	+	+	+	+	+
*Lagurus ovatus L.		+	+	+	
*Lolium perenne L.			+	+	+
*Lolium rigidum Gaud.		+	+	+	+
Microlaena stipoides (Labill.) R.Br.	+		+		
*Poa annua L.		+			
Poa drummondiana Nees		+	+	+	
Stipa compressa R.Br.		+	+	+	
Stipa flavescens Labill.			+	+	
*Vulpia bromoides (L.) S.F. Gray		+	+		+
*Vulpia myuros (L.) C.C. Gmelin					+

	Site record				
	1	2	3	4	5
Polygalaceae					
Comesperma confertum Labill.	+		+	+	
Polygonaceae					
*Emex australis Steinh.		+	+		
Muehlenbeckia adpressa (Labill.) Meisn.		+	+	+	
*Rumex acetosella L.			+		
Portulacaceae					
Calandrinia brevipedata F. Muell.	+		+		
Calandrinia calyptrata J.D. Hooker			+	+	
Calandrinia liniflora Fenzl				+	
Primulaceae					
Anagallis arvensis L.	+	+	+	+	
Proteaceae					
Banksia grandis Willd.			+		
Dryandra nivea (Labill.) R.Br.	+	+	+	+	
Dryandra sessilis (Knight) Domin.	+	+	+	+	
Grevillea vestita (Endl.) Meisn.				+	
Hakea prostrata R.Br.	+	+	+	+	
Hakea ruscifolia Labill.	+	+		+	
Persoonia graminea R.Br.	+				
Petrophile linearis R.Br.	+	+	+	+	
Ranunculaceae					
Clematis microphylla DC.	+	+	+	+	
Clematis pubescens Huegel	+		+	+	
Ranunculus colonorum Endl.			+	+	
Ranunculus sessiflorus R.Br.			+		
Restionaceae					
Loxocarya flexuosa (R.Br.) Benth.	+	+	+	+	
Rhamnaceae					
Blackallia connata (C.A. Gardner) C.A. Gardner		+	+	+	
Cryptandra arbutiflora Fenzl				+	
Spyridium globulosum (Labill.) Benth.	+		+	+	
Rubiaceae					
*Galium murale (L.) All.		+		+	
Opercularia hispidula Endl.	+				
Opercularia vaginata Labill.	+	+	+	+	
*Sherardia arvensis L.	+	+	+		
Rutaceae					
Diplolaena dampieri Desf.				+	
Eriostemon spicatus A. Rich.	+		+	+	
Scrophulariaceae					
*Bellardia trixago (L.) All.			+	+	
*Dischisma arenarium E. Meyer	+				
*Parentucellia latifolia (L.) Caruel	+	+	+	+	
*Parentucellia viscosa (L.) Caruel	+		+	+	
Solanaceae					
*Solanum nigrum L.			+		
*Solanum sodomeum L.	+	+	+	+	
Stackhousiaceae					
Stackhousia brunonis Benth.	+	+	+	+	
Stackhousia huegelii Endl.		+	+		
Sterculiaceae					
Thomasia cognata Steud.			+		
Thomasia triphylla (Labill.) J. Gray	+	+	+		

	Site record				
	1	2	3	4	5
Stylidiaceae					
Levenhookia pusilla R.Br.		+		+	
Levenhookia stipitata (Sonder) F. Muell.				+	
Stylidium adnatum R.Br.		+	+		
Stylidium calcaratum R.Br.			+	+	
Stylidium junceum R.Br.		+		+	
Stylidium striatum Lindl.		+	+	+	
Thymelaeaceae					
Pimelea rosea R.Br.	+	+	+	+	
Tremandraceae					
Tetratheca hirsuta Lindl.				+	
Tetratheca setigera Endl.	+		+		
Urticaceae					
Parietaria debilis G. Forster	+	+	+	+	
Violaceae					
Hybanthus calycinus (DC. ex Ging.) F. Muell.	+	+	+	+	

Fig. 1. Aerial photograph of rabbit study area with locations of vegetation communities depicted.

Fig. 2. *Agonis flexuosa* - woodland with herbland in foreground.

Fig. 3. *Acacia rostellifera* - open scrub. Note almost pure stand of *Acacia*.

Fig. 4. *Dryandra sessilis* - shrubland.

Fig. 5. *Xanthorrhoea preissii* - open heath.

WESTERN AUSTRALIAN HERBARIUM RESEARCH NOTES

No. 9, 1983: 15-26

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1. Western Australian Herbarium, Department of Agriculture, Jarrah Road, South Perth, Western Australia 6151.
2. Research Section, Agriculture Protection Board of Western Australia, Bougainvillea Avenue, Forrestfield, Western Australia 6058.

ABSTRACT

A botanical survey of a Rabbit Study Area at Chidlow recognised nine plant communities in three structural formations of vegetation. 240 plant species were recorded of which 183 were native and 57 were naturalised aliens.

The vegetation and flora of the RSA were typical of those present in the eastern Darling Range, under similar conditions of clearing and disturbance.

INTRODUCTION

The Rabbit Study Area (RSA) in the Darling Range at Chidlow (31°57'S, 116°19'E) lies due east and approximately 55 km from Perth. At the time the survey was conducted the area was being used by the Research Section of the Agriculture Protection Board for studying the biology and control of rabbit populations. The RSA Avon Location 3444, is an old farm which was resumed for water catchment. It covers an area of approximately 800 hectares of which about 40% is cleared, and is surrounded by native vegetation.

The area experiences a Mediterranean-type climate with an annual rainfall averaging 920 mm. The wettest six-monthly period is from May to October. The maximum mean temperatures are 30.8°C in February and 15.7°C in July, with the minimum temperature means for the same months being 17.5°C and 8.5°C respectively, recorded at Kalamunda (see Table 1).

The soil is heavy, being lateritic gravel on the upper slopes and heavy loam on the lower slopes and floodplain of the Helena River, a winter-flowing creek which passes through the area. The soils overlie granite which outcrops in localised patches.

The cleared area sown to pasture is situated on the floodplain and is surrounded by native vegetation, mostly *Eucalyptus* woodland with a low

Table 1. Mean maximum and minimum temperatures recorded at Kalamunda (32° 0'S, 116°4'E, elevation 317.0 M) and mean monthly rainfall recorded at Chidlow (31°52'S, 116°16'E, elevation 300.0 M). (Courtesy of Dept. of Science and Technology, Bureau of Meteorology, Perth).

	Daily Maximum Temperature (°C) Mean	Daily Minimum Temperature (°C) Mean	Rainfall (mm) Mean
JAN	29.3	15.9	11
FEB	30.8	17.5	17
MAR	28.1	15.4	19
APR	22.7	12.4	44
MAY	19.8	11.2	118
JUN	16.1	9.2	186
JUL	15.7	8.5	192
AUG	15.5	8.0	145
SEP	17.0	8.8	90
OCT	21.3	10.4	60
NOV	23.6	11.5	24
DEC	28.1	14.0	14
		ANNUAL TOTAL	920

sparse shrub and herb layer. The pasture is rank except in the vicinity of some of the larger groups of rabbit warren, where the grazing pressure of rabbits maintains a short sward.

There has been no domestic stock on the property since 1971, but there is some grazing by the Western grey kangaroo, *Macropus fuliginosus ocydromus*.

METHOD

The plant communities in the RSA were mapped by aerial photographic interpretation, supported by data obtained from ground traverses. The structural classification used follows that adopted by Aplin (1981).

Several locations in each of the vegetation communities were sampled floristically to provide a flora list of the area. Nomenclature follows Green (1981), and voucher specimens have been lodged at the Western Australian Herbarium (PERTH).

RESULTS

Three structural forms of vegetation were recognised. These consist of forest, woodland and herbland communities and are shown on the aerial photograph (Fig. 1).

Forest communities
1. Plantations of *Pinus radiata*.
2. Fringing forest of paperbarks, *Melaleuca rhaphiophylla*, along creeks (Fig. 2a).

Woodland communities
1. *Casuarina huegeliana* on granite outcrop.
2. *Eucalyptus wandoo* on granite and heavy loams (Fig. 2b).
3. *Eucalyptus calophylla* on loam (Fig. 2c).
4. *Eucalyptus marginata* on laterites.
5. *Eucalyptus patens* on alluvial soils of floodplain (Fig. 2d).
6. *Eucalyptus rudis* along creeks.

Herbland community
1. A man-made pasture land, consisting of annual species of naturalised aliens, situated on the floodplain.

240 plant species were recorded in the RSA, of which 183 were native and 57 were aliens. These are listed in Appendix 1. Most of the species were recorded in more than one of the vegetation communities.

The vegetation communities with the most number of alien species were *E. wandoo-E. calophylla-E. marginata* woodlands (44) and *E. patens* woodlands and associated herblands (41). *E. rudis* and *M. rhaphiophylla* fringing communities (32) and *C. huegeliana* woodland (23) contained lesser numbers of alien species.

The number of native species were also very much higher in the *E. wandoo-E. calophylla* (142) and *E. patens* (81) communities, than in the fringing (46) and *Casuarina* (39) communities.

194 of the total number of species were herbaceous annuals or short-lived perennials, while only 48 woody perennial species were present, these latter belonging to such families as the Casuarinaceae, Dilleniaceae, Epacridaceae, Leguminosae, Myrtaceae, Proteaceae and Thymelaeaceae.

DISCUSSION

The vegetation of the RSA was typical of the general region of the eastern Darling Range (Beard, 1981). *E. wandoo* and *E. calophylla* are dominant on valley sides with *E. patens* occupying the valley floors; *E. rudis* and *M. rhaphiophylla* typically fringing water courses; and *Casuarina huegeliana* being associated with granite rocks. *E. loxophleba* which is found in valleys of larger watercourses to the east was not present in the RSA.

The high proportion of naturalised alien species, 57 out of 240 (24%) must be attributed to the disturbances that had taken place while the RSA was a farm and by subsequent activities of man.

The botanical survey showed that a large proportion of plants, native and naturalized aliens, are probably important in the diet of rabbits.

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APPENDIX I

List of plant species

Families, genera and species are arranged alphabetically. The site record numbers refer to plant communities groups as follows:

1. *Eucalyptus wandoo*, *E. calophylla* and *E. marginata* woodlands.
2. *E. patens* and herbland on alluvial soils of floodplain.
3. *E. rudis* and *Melaleuca rhaphiophylla* on creek lines.
4. *Casuarina huegeliana* on granite outcrop.

* Introduced aliens

	Site Records			
	1	2	3	4
Adiantaceae				
Cheilanthes tenuifolia (N.L. Burman) Swartz	+			+
Amaranthaceae				
Ptilotus declinatus Nees	+	+		
Ptilotus drummondii (Moq.) F. Muell.	+		+	
Ptilotus humilis (Nees) F. Muell.			+	
Ptilotus manglesii (Lindl.) F. Muell.	+	+	+	
Apiaceae				
Daucus glochidiatus (Labill.) Fisch	+	+		
Eryngium pinnatifidum Bunge	+	+		
Homalosciadum homalocarpum (F. Muell.) Hj. Eichler				
Trachymene pilosa Sm.				+
Asteraceae				
Angianthus demissus (A. Gray) Benth.	+			
*Arctotheca calendula (L.) Levyns	+	+	+	+
Brachycome bellidioides Steetz	+			
Brachycome iberidifolia Benth.	+			
Calocephalus drummondii (A. Gray) Benth.	+			
Calotis erinacea Steetz	+			
*Carduus pycnocephalus L.	+	+	+	
Centipeda cunninghamii (DC.) A. Braun & Aschers			+	
*Conyza albida Spreng	+			
*Conyza bonariensis (L.) Cronquist	+		+	
*Dittrichia graveolens (L.) W. Greuter		+		
*Gnaphalium candidissimum Lamarck	+		+	
Gnaphalium gymnocephalum DC.			+	
Helichrysum bracteatum (Vent.) Andr.	+	+		
Helipterum corymbosum (A. Gray) Benth.	+			
Helipterum cotula (Benth.) DC.	+	+		
Helipterum demissum (A. Fray) Druce	+	+		

	Site Records 1	2	3	4
Helipterum hyalospermum F. Muell. ex Benth.	+			+
Helipterum manglesii (Lindl.) Benth.	+			
*Hypochoeris glabra L.	+	+	+	+
*Hypochoeris radicata L.	+	+		
Lagenifera huegelii Benth.	+	+		
Millotia tenuifolia Cass.		+		
Podolepis canescens A. Cunn. ex DC.	+	+		
Podolepis lessonii (Cass.) Benth.	+	+		+
Podotheca chrysantha (Steetz) F. Muell.	+	+		
Quinetia urvillei Cass.	+			+
Rutidosis multiflora (Nees) B.L. Robinson	+	+		
Senecio lautus G. Forster ex Willd.	+	+		+
Senecio quadridentatus Labill.	+	+		+
*Sonchus asper (L.) Hill	+	+	+	+
*Sonchus oleraceus L.	+	+	+	+
*Tolpis barbata (L.) Gaertn.	+			
*Ursinia anthemoides (L.) Poir	+	+		+
Waitzia citrina (Benth.) Steetz	+	+	+	
Waitzia paniculata F. Muell. ex Benth.	+			+
Brassicaceae				
*Raphanus raphanistrum L.	+	+		
Campanulaceae				
Wahlenbergia preissii De Vriese	+			
Caryophyllaceae				
*Cerastium glomeratum Thuill.	+	+	+	+
*Petrorhagia nanteuilii (Burnat) P.W. Ball & V.H. Heywood	+	+	+	+
*Silene gallica L.	+	+		
*Spergularia diandra Heldr. & Sart. ex Heldr.				+
Casuarinaceae				
Casuarina huegeliana Miq.				+
Centrolepidaceae				
Centrolepis aristata (R.Br.) Roemer & Schultes	+			
Clusiaceae				
Hypericum gramineum G. Forster		+	+	
Convolvulaceae				
Convolvulus erubescens Sims	+			
Crassulaceae				
Crassula bonariensis DC.	+			
Crassula colorata (Nees) Ostenf.	+	+	+	+
Cyperaceae				
Carex inversa R.Br.	+		+	
Cyperus gracilis R.Br.	+		+	
Cyperus tenellus L.f.	+		+	
Lepidosperma gracile R.Br.		+		
Schoenus grammatophyllus F. Muell.		+		
Dilleniaceae				
Hibbertia hypericoides (DC.) Benth.	+			
Hibbertia montana Steud.	+	+		
Hibbertia stellaris Endl.	+	+		
Droseraceae				
Drosera gigantea Lindl.	+	+	+	
Drosera glanduligera Lehm.	+	+	+	
Drosera microphylla Endl.	+	+	+	
Drosera pallida Lindl.	+	+		+
Drosera stolonifera Endl.	+			
Drosera stricticaulis (Diels) O.H. Sargent		+		

	Site Records 1	2	3	4
Epacridaceae				
Astroloma pallidum R.Br.		+		
Leucopogon propinquus R.Br.	+	+		
Euphorbiaceae				
Phyllanthus calycinus Labill.	+	+	+	+
Poranthera ericoides Klotzsch	+			
Gentianaceae				
*Centaurium erythraea Rafn.	+			
Geraniaceae				
*Erodium botrys (Cav.) Bertol.	+	+	+	+
*Erodium cicutarium (L.) L'Herit.	+			
Geranium solanderi Carolin	+		+	+
Pelargonium littorale Huegel			+	+
Goodeniaceae				
Dampiera alata Lindl.		+		
Dampiera cuneata R.Br.	+	+		
Dampiera linearis R.Br.	+	+		
Lechenaultia biloba Lindl.	+	+		+
Scaevola striata R.Br.	+	+		
Velleia trinervis Labill.	+	+	+	
Haemodoraceae				
Conostylis setigera R.Br.	+	+	+	
Haemodorum paniculatum Lindl.	+	+	+	+
Tribonanthes uniflora Lindl.		+	+	
Haloragaceae				
Gonocarpus nodulosa Nees		+		
Hypoxidaceae				
Hypoxis leptantha Benth.		+		
Iridaceae				
*Gladiolus caryophyllaceus (N.L. Burman) Poir	+			+
Orthrosanthus laxus (Endl.) Benth.	+			
Patersonia occidentalis R.Br.	+			
Patersonia umbrosa Endl.	+			
*Romulea rosea (L.) Eckl.	+	+	+	+
Juncaceae				
*Juncus bufonius L.			+	
Juncus pallidus R.Br.		+	+	
Juncus pauciflorus R.Br.	+			
Luzula meridionalis Nordensk	+		+	
Juncaginaceae				
Triglochin procera R.Br.			+	
Lamiaceae				
*Stachys arvensis (L.) L.	+	+	+	
Leguminosae - subfamily Mimosoideae				
Acacia diptera Lindl.		+		
Acacia pulchella R.Br.	+	+	+	
Acacia rostellifera Benth.		+		
Acacia saligna (Labill.) H.L. Wendl.		+		
Leguminosae - subfamily Papilionoideae				
Bossiaea eriocarpa Benth.	+			
Bossiaea ornata (Lindl.) Benth.	+	+		
Daviesia divaricata Benth.	+			
Daviesia hakeoides Meisn.		+		
Gastrolobium calycinum Benth.		+		
Gastrolobium villosum Benth.	+			

	Site Records 1	2	3	4
Gompholobium marginatum R.Br.	+	+		
Gompholobium tomentosum Labill.				+
Isotropis cuneifolia (Sm.) Benth.	+			
Kennedia coccinea Vent.	+		+	+
Kennedia prostrata R.Br.	+	+	+	+
*Lotus subbiflorus Lag.		+		
*Lupinus cosentinii Guss.	+		+	
*Medicago polymorpha L.		+		
Oxylobium capitatum Benth.	+	+		
*Trifolium arvense L.	+		+	+
*Trifolium campestre Schreber	+	+	+	+
*Trifolium subterraneum L.	+	+	+	
Lentibulariaceae				
Polypompholyx tenella (R.Br.) Lehm.	+			
Liliaceae				
Agrostocrinum scabrum (R.Br.) Bail.		+		
Arthropodium capillipes Endl.	+			
Borya nitida Labill.	+	+		+
Bulbine semibarbata (R.Br.) Haw.				+
Burchardia umbellata R.Br.	+	+		
Caesia parviflora R.Br.	+			
Chamaescilla corymbosa (R.Br.) F. Muell. ex Benth.	+	+		
Lomandra caespitosa (Benth.) Ewart	+			
Lomandra preissii (Endl.) Ewart		+		
Sowerbaea laxiflora Lindl.	+	+		
Stypandra grandiflora Lindl.	+	+		+
Stypandra imbricata R.Br.	+			
Thysanotus isantherus R.Br.	+			+
Thysanotus patersonii R.Br.	+	+		
Tricoryne elatior R.Br.	+	+		
Tricoryne humilis Endl.	+			
Wurmbea dioica (R.Br.) F. Muell.		+		
Xanthorrhoea preissii Endl.	+	+	+	+
Linaceae				
Linum marginale A. Cunn. ex Planch	+	+		
Lobeliaceae				
Isotoma hypocrateriformis (R.Br.) Druce	+	+		
Isotoma pusilla Benth.	+		+	
Isotoma scapigera (R.Br.) G. Don.	+			
Lobelia alata Labill.			+	
Lobelia tenuior R.Br.	+			
Loganiaceae				
Mitrasacme paradoxa R.Br.	+			
Lythraceae				
Lythrum hyssopifolia L.		+	+	
Myrtaceae				
Eucalyptus calophylla Lindl.	+			
Eucalyptus marginata Donn ex Sm.	+		+	
Eucalyptus patens Benth.	+	+		
Eucalyptus rudis Endl.	+		+	
Eucalyptus wandoo Blakely	+			
Hypocalymma angustifolium Endl.	+			+
Leptospermum erubescens Schauer	+			
Melaleuca rhaphiophylla Schauer			+	

	Site Records 1	2	3	4
Orchidaceae				
Caladenia filamentosa R.Br.	+			
Caladenia flava R.Br.	+	+		
Caladenia gemmata Lindl.	+			
Caladenia huegelii H. Reichenb	+			
Diuris laxiflora Lindl.			+	
Diuris longifolia R.Br.	+	+		+
Prasophyllum triangulare Fitzg.	+			
Thelymitra antennifera (Lindl.) J.D. Hooker		+		
Thelymitra canaliculata R.Br.			+	
Orobanchaceae				
Orobanche australiana F. Muell.	+			
Oxalidaceae				
Oxalis corniculata L.	+	+		+
Pinaceae				
*Pinus radiata D. Don	X			
Pittosporaceae				
Billardiera bicolor (Putterl.) E.M. Bennett		+	+	
Poaceae				
*Aira caryphyllea L.	+	+		+
*Avena barbata Link	+	+	+	+
*Briza maxima L.	+	+	+	+
*Briza minor L.	+	+	+	+
*Bromus diandrus Roth.	+	+	+	+
*Bromus hordeaceus L.	+	+		
*Bromus madritensis L.	+			
Danthonia caespitosa Gaud.	+	+		+
*Ehrharta longiflora Sm.	+	+	+	
*Eragrostis curvula (Schrad.) Nees		+	+	
Eriachne ovata Nees	+			
*Holcus lanatus L.	+	+	+	
*Holcus setiger Nees		+	+	
*Hordeum leporinum Link		+		
*Lolium rigidum Gaud.		+	+	
Microlaena stipoides (Labill.) R.Br.	+		+	+
Neurachne alopecuroidea R.Br.	+	+		+
*Poa annua L.	+		+	
Poa drummondiana Nees			+	
Stipa elegantissima Labill.	+			
Stipa semibarbata R.Br.	+	+		+
Stipa trichophylla Benth.	+	+	+	+
*Vulpia bromoides (L.) S.F. Gray	+	+		+
*Vulpia myuros (L.) C.C. Gmelin	+	+		
Polygalaceae				
Comesperma calymega Labill.	+			
Polygonaceae				
Muehlenbeckia adpressa (Labill.) Meisn.	+			+
Polygonum prostratum R.Br.		+		
*Rumex acetosella L.		+		
*Rumex pulcher L.	+	+		
Portulacaceae				
Calandrinia calyptrata J.D. Hooker			+	

X Plantations

	Site Records			
	1	2	3	4
Primulaceae				
*Anagallis arvensis L.	+	+	+	+
Proteaceae				
Dryandra nivea (Labill.) R.Br.	+	+		
Grevillea paniculata Meisn.		+		
Hakea prostrata R.Br.	+	+	+	
Ranunculaceae				
Clematis pubescens Huegel ex Endl.	+			
Ranunculus colonorum Endl.			+	
*Ranunculus muricatus L.		+		
Restionaceae				
Leptocarpus coangustatus Nees	+	+	+	
Loxocarya flexuosa (R.Br.) Benth.	+			
Rhamnaceae				
Trymalium ledifolium Fenzl.	+			
Trymalium spathulatum (Labill.) Ostenf.	+			
Rosaceae				
Acaena ovina A. Cunn.	+	+		
Rubiaceae				
*Galium divaricatum Lamarck	+		+	
*Galium murale (L.) All.	+	+		+
Santalaceae				
Leptomeria axillaris R.Br.	+			
Leptomeria cunninghamii Miq.	+			
Sapindaceae				
Diplopeltis huegelii Endl.	+			
Scrophulariaceae				
*Bellardia trixago (L.) All.		+		
Gratiola peruviana Linn.		+		
*Kickxia spuria (L.) Dumort.	+		+	
*Parentucellia latifolia (L.) Caruel	+	+	+	+
Solanaceae				
Nicotiana rotundifolia Lindl.				+
*Solanum nigrum L.	+	+	+	+
Stackhousiaceae				
Stackhousia pubescens A. Rich	+	+	+	+
Sterculiaceae				
Thomasia triphylla (Labill.) J. Gray		+		
Stylidiaceae				
Levenhookia pusilla R.Br.	+			
Levenhookia stipitata (Sonder) F. Muell.	+			
Stylidium brunonianum Benth.	+	+		
Stylidium bulbiferum Benth.	+	+		+
Stylidium calcaratum R.Br.	+			+
Stylidium caricifolium Lindl.	+			
Stylidium ciliatum Lindl.	+			+
Stylidium petiolare Sond.	+	+		
Thymelaeaceae				
Pimelea argentea R.Br.	+			
Pimelea rosea R.Br.	+	+		
Pimelea spectabilis (Fisch. & Mey.) Lindl.	+			
Urticaceae				
Parietaria debilis G. Forster	+			
Zamiaceae				
Macrozamia reidlei (Gand.) C.A. Gardn.	+	+	+	+

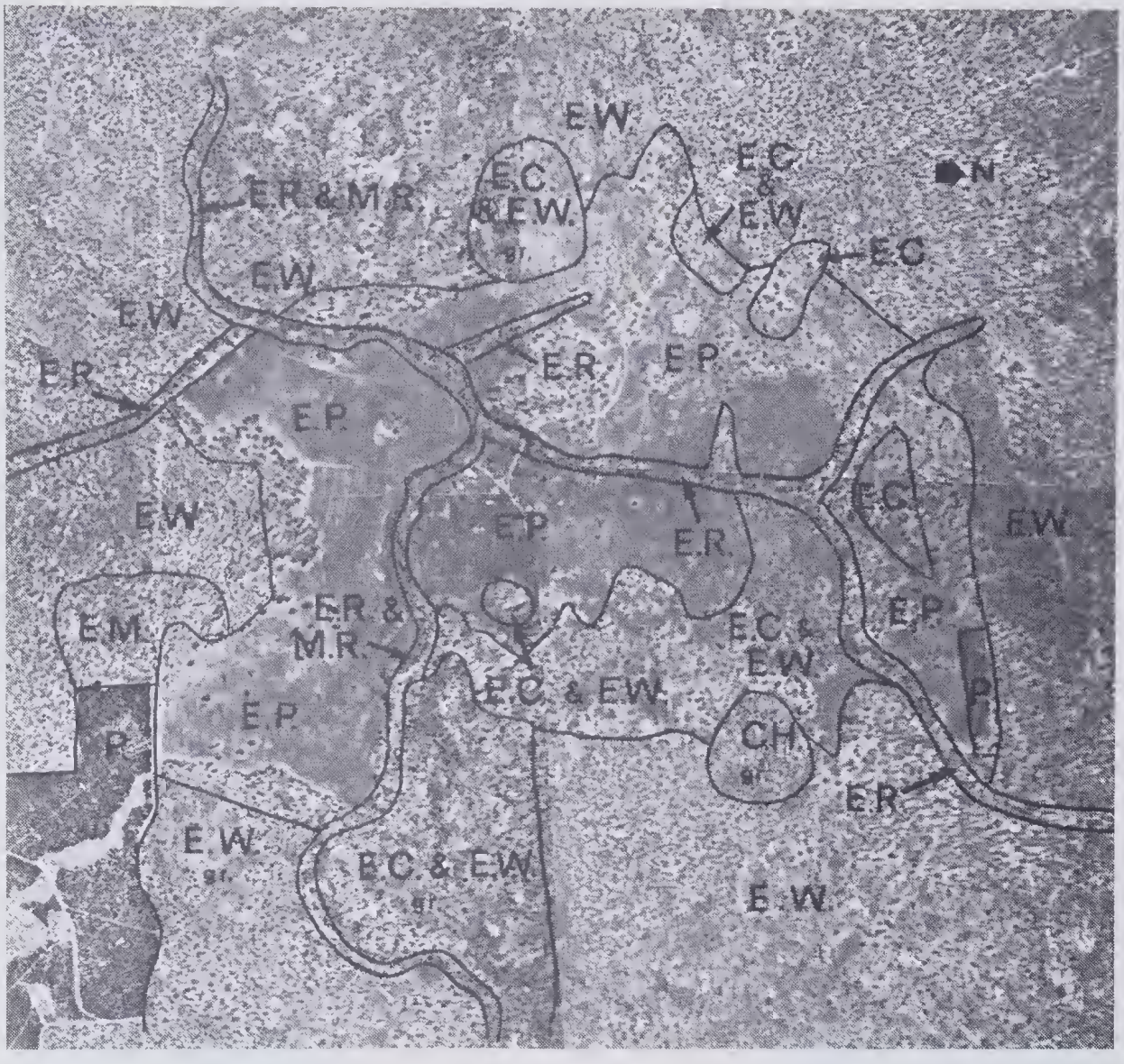

Fig. 1. Aerial photograph of rabbit study area at Chidlow with locations of vegetation communities depicted.
P = *Pinus radiata* plantations; M.R. = *Melaleuca raphiophylla* along creeks; E.R. = *Eucalyptus rudis* along creeks; C.H. = *Casuarina huegeliana*; E.W. = *Eucalyptus wandoo*; E.C. = *Eucalyptus calophylla*; E.M. = *Eucalyptus marginata*; E.P. = *Eucalyptus patens*; gr = granite outcrops.

Fig. 2. *Melaleuca rhaphiophylla* along creek, pasture in foreground.

Fig. 3. *Eucalyptus wandoo* woodland in background, pasture and *Xanthorrhoea preissii* in foreground.

Fig. 4. *Eucalyptus calophylla* with *Eucalyptus wandoo* woodland in background, pasture in foreground.

Fig. 5. *Eucalyptus patens* woodland, pasture understorey.

WESTERN AUSTRALIAN HERBARIUM RESEARCH NOTES

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DRAINAGE, SWAMP STRUCTURE AND VEGETATION SUCCESSION AT MELALEUCA PARK, NORTHERN SWAN COASTAL PLAIN

By B.G. Muir

National Parks Authority of Western Australia, Hackett Drive, Nedlands 6009.

Previous Address: Biological Survey Unit, Western Australian Museum, Francis Street, Perth 6000.

ABSTRACT

The relationships between water-table, soil drainage, swamp structure and vegetation in Melaleuca Park are examined. Changes likely to occur in the vegetation as a consequence of lowering of the water-table by pumping from bores are suggested.

INTRODUCTION

Melaleuca Park (hereafter referred to as the Park) is situated on the northern Swan Coastal Plain ca. 25 km north-northeast of Perth between Wanneroo and Bullsbrook.

The Park consists of about 3000 ha of natural vegetation bounded on its south and west sides by pine plantations, on its east side by cleared farmland and market gardens and on its north side by natural vegetation (Royal Australian Air Force facilities and bombing range). It is controlled by the Western Australian Forests Department which set aside the land as a reserve "for conservation purposes and for providing a basis for future long term studies of the relative productivity and ecological stability of natural forest" (letter from Forests Department to Western Australian Naturalists Club, 3 December, 1974).

The Park is situated on the Bassendean Sand System, an area of highly leached Pleistocene sand dunes with sandy or peaty swamps in the interdunal depressions. The mean annual rainfall is approximately 840 mm (based on data from Wanneroo and from Pearce Airforce Base, Bullsbrook - Bureau of Meteorology, unpublished data).

The vegetation of the Perth region has been described by Speck (1952) and placed by Beard (1981) in the Bassendean Vegetation System. Havel (1968) used ordination techniques to assess the ecological factors determining the distribution of many plant species in natural vegetation north of Perth including sites in Melaleuca Park. In addition, Havel (1975), and Carbon (1976) have discussed possible changes to flora and fauna of the Bassendean Dune System if changes in water-table depth should occur following water

extraction from the Gnangara Water Mound.

The Gnangara Water Mound itself, is a dome-shaped aquifer which owes its form to drainage at the Moore River on the north, the sea on the west, the Swan River on the south, and Ellen Brook on its eastern borders. A programme is underway to extract large quantities of water from the mound to supplement Perth's water supply, and there are fears that the consequent lowering of the water-table may ultimately lead to loss of coastal vegetation in its vicinity.

The study described here was carried out between June and February 1977, with the assistance of members of the Western Australian Naturalists Club.

METHODS

Forty-five sites were studied at the Park (see Fig. 1). The Park was also traversed several times to observe vegetation in areas between sites. Some plant species for the succession study were collected and identified by members of the Western Australian Naturalists Club during 1976; the remainder were collected and identified by the author in 1977.

Canopy cover of the vegetation formations was visually estimated using the categories 2-10%, 10-30%, etc. in conformity with recent vegetation classifications e.g. Beard-Webb (1974), Muir (1977). These estimates were checked by occasional line-transects. Average foliage density was determined using a Spherical Densiometer (type A) as described by Lemmon (1956).

Swamp depth was measured from the margin, where the aquatic or semi-aquatic vegetation gave way to *Banksia* woodland. This transition line was nearly always clearly visible and closely corresponded to a contour around the swamp edge. From at least two points on this transition line sightings were taken into the swamp using an Abney Level. Sightings were made onto a tree or in swamps without trees onto a pole which was place therein. The height of the target point above the swamp floor was then measured.

Swamp areas were calculated from 1:25,000 air photographs (June 1976) by drawing the boundaries of the swamps directly onto the photographs and then superimposing on them a grid of squares of known area.

Soil moisture samples were taken at 0.5 m depth at each site and placed immediately into thick plastic bags and sealed. Samples were weighed in the laboratory, then dried at 100°C in a draight until their weight was constant. Finally, they were cooled to room temperature and weighed again. Water content was expressed as percentage by weight of the original sample.

Soil profiles were examined and described (Appendix 1) to a depth of 2 m or to the water-table (whichever came first) according to the methods of Northcote (1971). Soil pH was determined with a Pye Unicam (Model 293) pH meter. Samples were prepared by mixing 20 grams of soil with 100 c.c. 0.01 M calcium chloride solution and agitating for five minutes before testing. Total soluble salts were determined using a Philips PW9504 conductivity meter fitted with a PW9510 electrode. Samples were prepared in the same way as those for pH, but deionised water rather than calcium chloride solution was used in sample preparation.

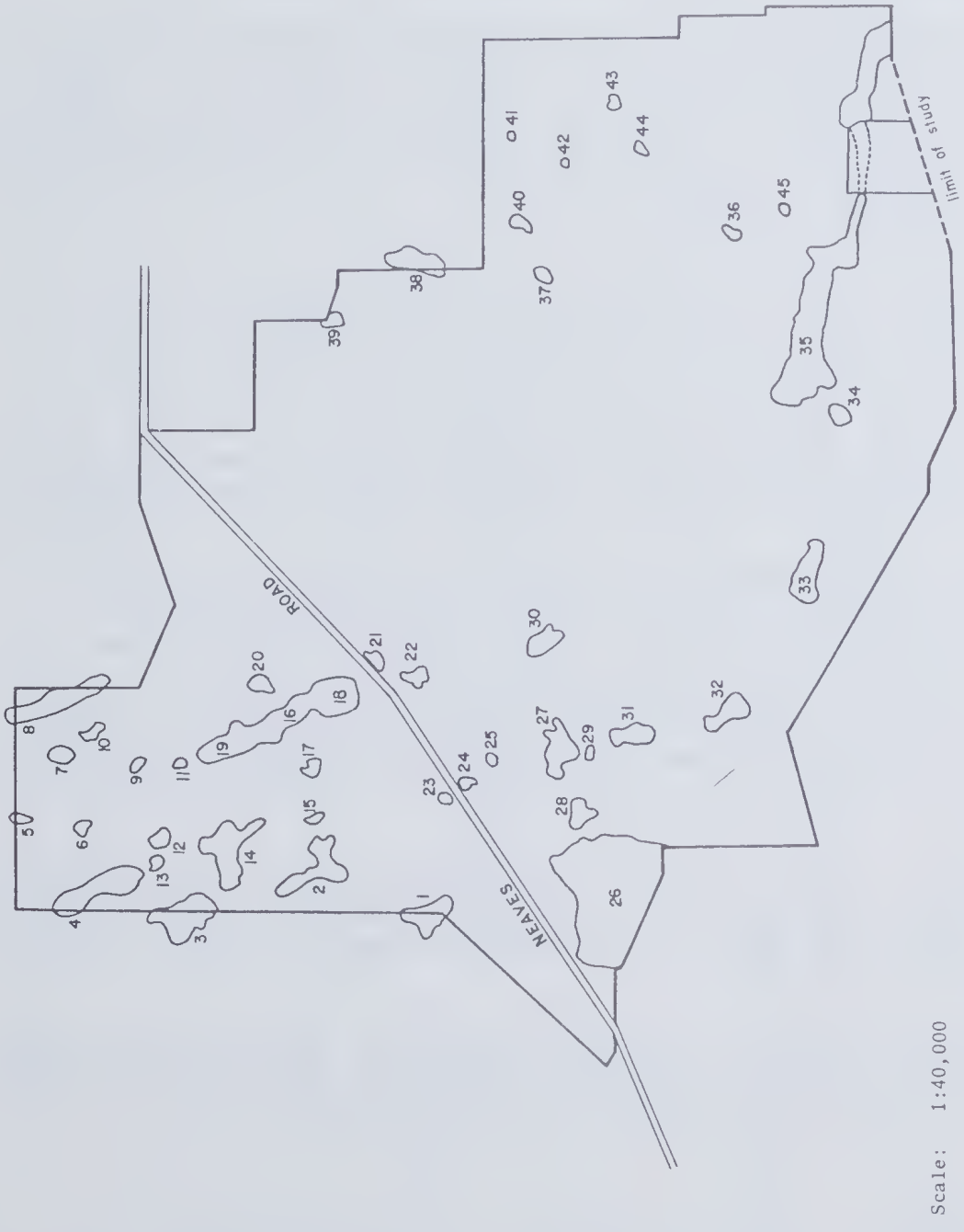

Fig. 1. Melaleuca Park, showing locations of swamps studied.

RESULTS AND DISCUSSIONS

Drainage and woodland physiognomy

About 90% of the Park is woodland of varying composition and structure; the remainder is swampland. Table 1 shows variation in dominance and physiognomy of woodland between the driest, best drained areas (dune tops) and the damper poorly drained areas (interdunal depressions).

It is apparent from the table that *Banksia attenuata* has the widest range of moisture tolerance, with *B. menziesii* adapting better to drier conditions and being replaced by *B. ilicifolia* in damper soils. *Eucalyptus todtiana* is scattered throughout the Park, but is never dominant and rarely found on dune tops, occurring mostly on slopes and in depressions which are too dry to support *E. marginata*. *E. marginata* is more or less restricted to the damper areas and swamp ecotones.

Canopy cover of the *Banksia* stratum varies little over the range of soil moisture (Fig. 2) but stratum height and Average Foliage Density (AFD) do vary. Table 1 shows that in the driest situations the Banksias are shorter in stature and that the thickness of the stratum (distance from bottom to top) is less, ca. 3 m on dune tops and ca. 8 m in other areas. Similarly, trees on dunes have sparser canopies (AFD 30% on dunes, ca. 50% in other areas). The lower AFD of 40% in *E. marginata* areas is because this species averages 25-30% AFD which lowers the average figure for the entire stratum. AFD of *Banksia* alone in the *E. marginata* zone remains at about 50%.

In stratum 2 the greatest variation with drainage is in floristic composition. The best drained sites have *Jacksonia floribunda* and *Adenanthos cygnorum* and this gives way to *Xanthorrhoea preissii* and other shrubs on the upper slopes and in depressions and *E. marginata* areas. Stratum height and canopy cover vary with species composition, although variation in canopy cover is greatest on the slopes. AFD in stratum 2, like that of woodland, is lowest on hill tops and marginally higher elsewhere, although this probably reflects changed species composition rather than variation due to water availability.

Stratum 3 in most situations is mixed heath with no particular dominants. In very slight depressions on slopes or flats *Dasypogon bromeliifolius* may become dominant. In much wetter depressions *Adenanthos obovatus* and *Regelia ciliata* become dominant.

There is little variation in either stratum height or thickness other than that due to changes in floristic composition. There is a trend towards denser post-fire regeneration in the moister sites, although the canopies themselves are also slightly denser in the drier sites.

Swamp Structure

Ten percent of the area of the Park is wetland of various types, from open swamps to damp depressions. The majority of swamplands are interdunal depressions. Figure 3 illustrates that in 35 of the 45 (78%) wetlands examined there is a direct relationship between depth and area. This would be expected where interdunal depressions are saucer-shaped and the swamp floors are of slightly varying height above the water-table.

Table 1. Variation in characteristics of vegetation at sites varying from highest to lowest points.

Character	Stratum	Dunes & tops of Rises	Slopes & Flats	Depressions within woodlands	Eucalyptus marginata areas
Dominants	1.	Banksia attenuata B. menziesii	B. attenuata B. menziesii Scattered B. ilicifolia	B. attenuata B. ilicifolia Scattered B. menziesii	B. attenuata B. ilicifolia E. Marginata
Height of bottom of stratum		4 m	2 m	2 m	2 m Jarrah 3 m
Height of top of stratum		7 m	10 m	10 m	10 m Jarrah 14 m
Canopy Cover		2-10%	2-10%	2-10%	2-10%
Average Foliage Density		50%	50%	50%	40%
Dominants	2.	Jacksonia floribunda Adenanthos cygnorum	Xanthorrhoea preissii or X. preissii - mixed shrubs	X. preissii	X. preissii
Height at bottom of stratum		0.5 m	0-0.5 m	0 m	0 m
Height at top of stratum		4 m	0-5.2 m	1.5 m	1.5 m
Canopy Cover		2-10%	0-20%	2-10%	2-10%
Average Foliage Density		10%	15%	15%	15%
Dominants	3.	Mixed shrubs	Mixed or mixed shrubs Dasypogon bromeliifolius	Adenanthos obovata, Regelia ciliata mixed shrubs	Mixed shrubs
Height at bottom of stratum		0 m	0 m	0 m	0 m
Height at top of stratum		0.5 m	0.5 m	1 m	1 m
Canopy Cover		30%	2-30%	30-70%	70-80%
Average Foliage Density		40%	30%	30%	30%

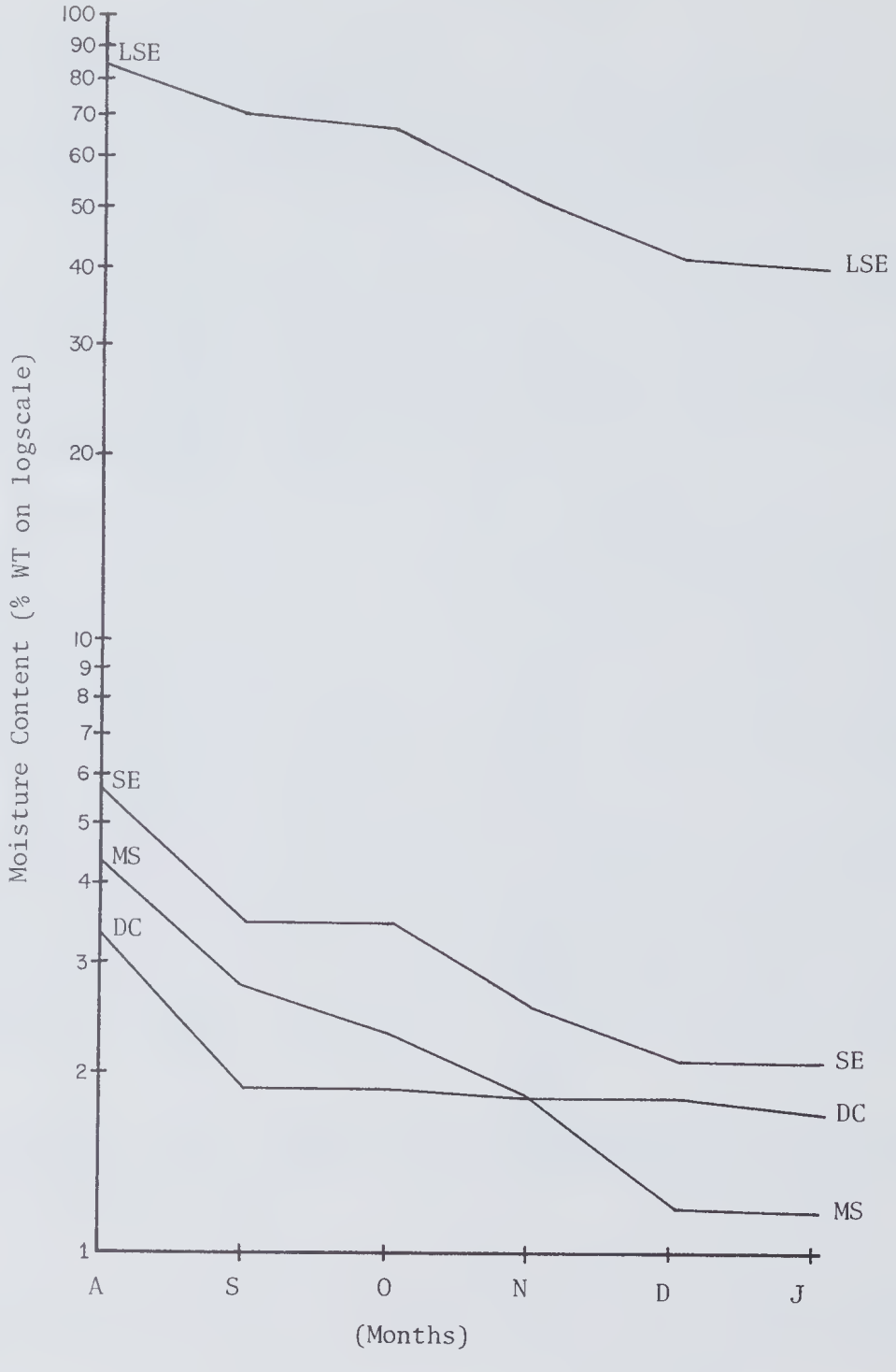

Fig. 2. Variation in soil moisture content over spring and early summer.

DC = dune crest
MS = midslope
SE = swamp edge
LSE = lower swamp edge

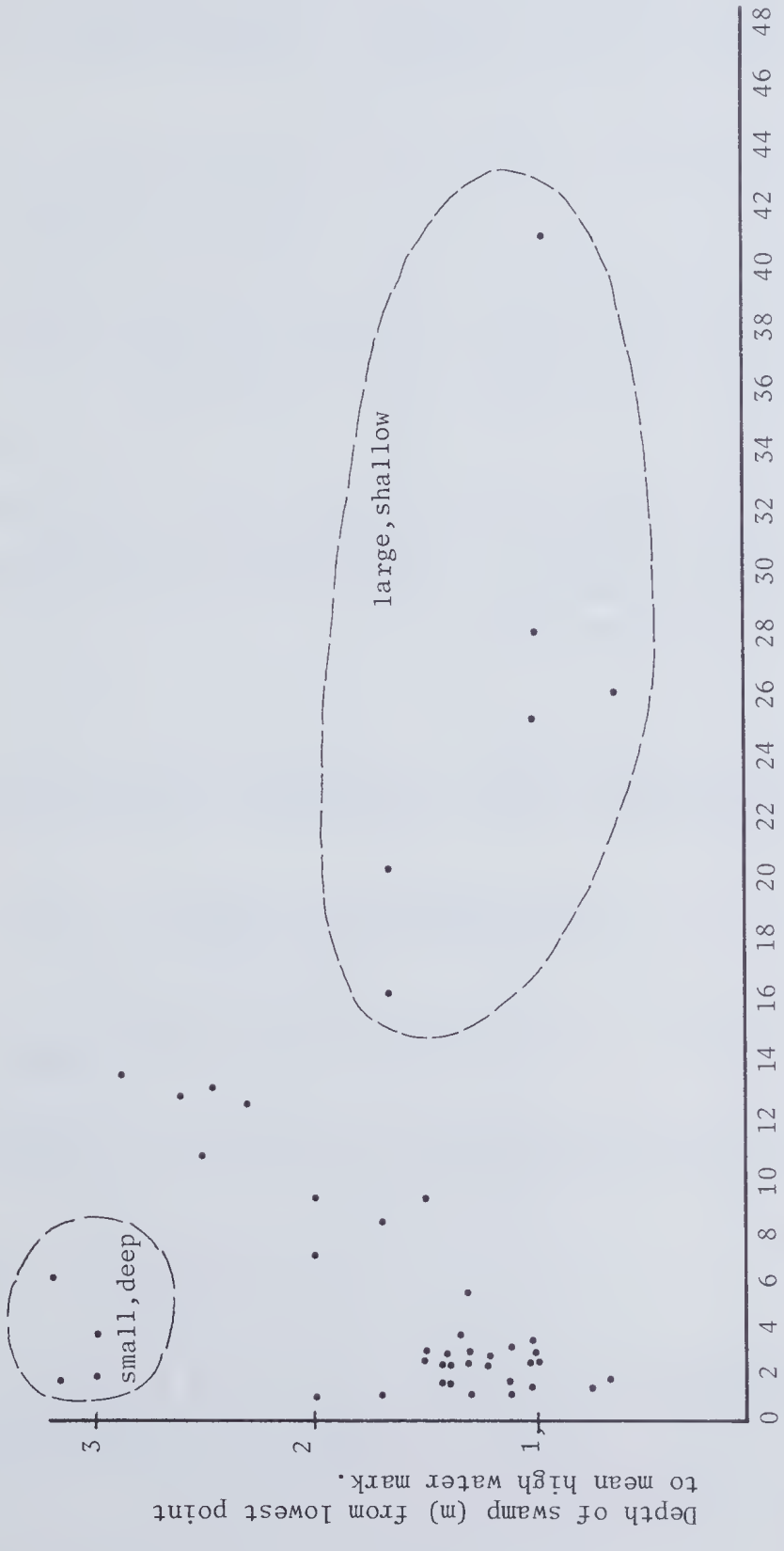
small, deep
large, shallow
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
AREA (ha)
3
2
1
Depth of swamp (m) from lowest point to mean high water mark.

Fig. 3. Relationship between swamp depth (lowest point to mean high water mark) and area as determined from air photographs. Note the almost linear relationship, except for a few small, very deep swamps, and a few large, shallow ones.

This proposition is supported by observations that 25 of the 45 (56%) swamps are less than 3 ha in area, and that 10 of these are in the south-east corner of the Park. Regular dune patterns would be expected to produce numerous small interdunal wetlands particularly to the south-east where dunes are of short wavelength and low amplitude. Swamps shallower than 1 m and smaller than 1 ha. in area are difficult to define as they begin to merge imperceptably into the surrounding woodland.

The remaining 10 of the 45 swamps examined are of two types: small in area and unusually deep (4), or large in area and unusually shallow (6). The small deep swamps are all in the north-west side of the Park where dunes are more pronounced and were commonly located at deep points in shallower north-west-trending depressions. Deep swamps of small area all have a similar sequence of ecotones, *Melaleuca preissiana* and *Astartea fascicularis* passing into *Pultenaea reticulata* then passing into woodland. Thus the sequence is the same as the majority of swamps, but abbreviated.

Broad shallow swamps, in contrast, provide a greater number of subtle variations in soil and drainage, the slopes being much broader and of lesser incline. Swamps of this type tend to have dominatns or co-dominants not found elsewhere, such as *Eucalyptus rudis* in stratum 1, or *Agonis linearifolia, Calothamnus lateralis* or *Leptocarpus scariosus* in stratum 2. The broad shallow swamps are remnants of large drainage systems which formerly drained to the south-east or the south-west.

Swamp Succession

The succession of vegetation types in the majority of swamps follows a difinite pattern, but often with abbreviated sequences. A typical complete sequence is as follows:

Baumea articulata	Only in wettest areas where free water persists well into summer.
Melaleuca preissiana over *Astartea fascicularis*	Present in the majority of swamps, completely covering the central area or as an ecotonal band around *Baumea* stands.
Leptospermum ellipticum	Commonest where incline of swamp edge is shallowest and may experience flooding in wet years.
Pultenaea reticulata	On upper slopes of depression where soil is peaty and becomes very wet but rarely waterlogs. May be in association with *Regelia* or *Hypocalymma* or as a pure stand.
Regelia ciliata/Hypocalymma angustifolium	Upper edges of depression in parts where soil is sandy and becomes very wet but rarely waterlogged. May support *Eucalyptus rudis*.
Banksia woodland	The transition from *Regelia/Hypocalymma* to *Banksia* woodland may have complex sub-ecotones of *Eucalyptus marginata, Dasypogon bromeliifolius Xanthorrhoea preissii*.

This basic sequence has numerous subtle variations, some of which are:

1. *Baumea articulata* is more or less restricted to the wettest swamps which are commonly also the best for peat development. As a consequence the two largest of the six swamps with *Baumea* have already been mined and their *Baumea* stands all but destroyed.

2. *Melaleuca rhaphiophylla* may replace *M. preissiana* in some swamps or occur together with it. In all cases *M. rhaphiophylla* frequents the wettest soils, usually those where the water-table lies above the surface during winter.

3. *Leptospermum ellipticum* is absent from many of the swamps, the majority passing more or less directly from *M. preissiana/Astartea fascicularis* stands directly into *Pultenaea, Regelia* or *Hypocalymma*. I believe its limited distribution is due to a preference for broad shallow swamp edges. Such a habitat is, of course, easily altered by minor changes in water level.

4. Occasionally, on the steepest sides (usually western) of swamps, or in swamps which are passing rapidly into woodland and have almost lost their identity, *Adenanthos cygnorum* and *Verticordia nitens* are abundant. These species do not form part of the swamp succession but grow opportunistically in the best drained locations where water is freely available. Where they occur in deep depressions in *Banksia* woodland they occupy sites of old swamps now filled with sand. This sand is well drained but abundant water is available at depth. For the same reasons, these species (particularly *A. cygnorum*) are very abundant on dune tops and in areas of regrowth following clearing of road verges. In all these situations water is available at depth (with additional runoff on road verges), and yet the topsoil is disturbed or otherwise very well drained.

5. *Banksia ilicifolia* penetrates further into the swamp than any other species of *Banksia*. The *Banksia* woodland on swamp edges may be of the form discussed in "*Eucalyptus marginata* areas" or "Depressions within woodland" in Table 1 above.

6. *Kunzea ericifolia* may be present as scattered plants or as a dominant throughout any of the drier ecotones.

7. *Pultenaea reticulata* appears to be very dependent on the depth of the water-table. The dry winters of 1976 and 1977 caused very high mortality on swamp margins throughout the Park.

Changes in Water Level

McComb and McComb (1967) state that the water level in Loch McNess (situated ca. 22 km north-west of the Park) could possibly have risen in the past, and that there appears to be a succession from open water, through sedge communities, to woodland. Records show that water levels in Lake Jandabup, ca. 6 km to the south-west of the Park, have risen slowly over the last 100 years, presumably as a result of clearing of surrounding vegetation and the increased runoff from roadways and buildings (A. Douglas, pers. comm.)

In the Park there is strong evidence to indicate that the water-table has fallen and that sand from adjacent dunes has begun to move into some swamps. *Melaleuca preissiana* sometimes occurs in two distinct belts separated by dense

Leptospermum ellipticum stands: an outer belt of large, very old trees, and and inner belt of much younger ones. A similar sequence sometimes occurs where there is an outer belt of *Melaleuca rhaphiophylla* (to 10 m tall and up to 1 m in girth) outside a belt of *M. preissiana* (6 m tall and mostly less than 15 cm in girth). As *M. rhaphiophylla* prefers waterlogged winter conditions and *M. preissiana* prefers drier sites, this sequence indicates that the stands of *M. rhaphiophylla* are probably remnants from a period with a much higher water-table. A decline in the water-table has allowed *M. preissiana* to establish itself within the *M. rhaphiophylla* band. Presumably the water-table declined so quickly that a slow advance of *M. rhaphiophylla* was not possible.

Such successions suggest a decline in water-table as well as a filling in of swamps with sand. In a few places in the Park, scattered senescent or dead *M. preissiana* trees are visible in areas of woodland, suggesting that a swamp was once present which has now been totally reclaimed by woodland and the depression completely filled in. Matiski (per. comm.) has also noted such sand filled swamps at Tick Flat, 15 km north of the Park.

Some swamps show sand fill gradually moving in from the edges, although they may be well vegetated at present. Swamps may have peat at depth as much as 10 m outside the present peat to sand transition area (see profiles, Appendix 1).

CONCLUSIONS

Assuming that the water-table will undergo severe local lowering near boresites as pointed out by Havel (1975), it is unlikely that the vegetation will be able to cope with the proposed water extraction programme at the Gnangara Water Mound and many plants will die. Havel's figure 13 shows death of Marri (*Eucalyptus calophylla*) trees near such a bore. Havel points out however that there should also be a moderate, slow decrease in the overall water-table. The data presented here indicates some of the changes in vegetation which may occur.

Specifically, *Banksia menziesii* can be expected to replace *B. attenuata* on dune slopes, being better adapted to drier conditions. *Banksia attenuata* will probably persist in damper areas but *B. ilicifolia*, being very dependent on moisture availability, may succumb completely. It has been observed by myself, by J. Dell (pers. comm.) and by R. Hunt (pers. comm.), that many species of insects and some birds may be dependent for food on the nectar of these *Banksias*. The flowering times of the three species overlap very little, one ceasing to flower when another is beginning. This provides an almost continuous nectar supply throughout the year. Either the loss of *B. ilicifolia* or a reduction in the abundance of *B. attenuata* could seriously affect dependent fauna.

Other changes to be expected are decreases in stratum height and average foliage density as sites become drier. The significance of stratum height and density to bird utilisation of habitats is well recognised (Cody 1965; Hilden 1965; MacArthur and MacArthur 1961).

Changes in floristic composition occur concurrently with changes in structure. The loss of particular plant species may be important to the habitat of ground fauna. For example *Dasypogon bromeliifolius*, which is likely to be lost, except perhaps in the remnants of swamps, is thought to

provide shelter for reptiles (G. Barron, pers. comm.; G. Harold, pers. comm.).

Adenanthos obovatus, which exists only in damp (not swampy) locations, is likely to decline as such sites dry out following a fall in water table. This species in the Park has been observed by J. Dell (pers. comm.) to be a major food source for the Western Spinebill (*Acanthorhynchus superciliosus*).

Leptospermum ellipticum and *Astartea fascicularis* could also be expected to decline. The significance of these species to native fauna is not known, but they both have been observed to attract many species of insects, including Jewel Beetles (Astereidae). Some of these insects could be important in the diet of insectivorous fauna.

The observations that *Melaleuca preissiana* replaces *M. rhaphiophylla* in some swamps suggest a decline in water-table in relatively recent times. It is not known if this decline is a consequence of a natural change in climate or of alteration of the environment by man. It is however an indication that changes to drier conditions have occurred and it increases the likelihood that any future man-induced changes to the water-table may have further drastic effects.

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APPENDIX 1 - TYPICAL SOIL PROFILES

Soil profiles were examined in a number of sites and are set out in some detail below. The soils were of two types: almost pure quartz sand, strongly leached, on dune tops and slopes (woodland areas); and peat with various proportions of sand in depressions and swamps. Sandy soils were all acid, dune tops averaging pH 3.8 and woodland flats and slopes pH 4.2 (average of 30 cm and 1 m samples taken March and July). The acid pH on slopes is probably due to a higher organic content (see profiles). Total dissolved salts (TDS), was very low on both dune tops and slopes, averaging 25 ppm and 30 ppm respectively.

Swamp vegetation is on soils of peaty origin. The centre of open swamps examined averages pH 4.9 and 200 ppm TDS. The higher pH than woodland soils is probably the result of some sort of buffering effect by the peat. The higher TDS may reflect a "sink" effect for salts from surrounding dunes. If this is so, one would expect higher salt content in the swamps than is apparent.

It was noted that surface water appeared in swamp B Fig. 1 in late March although there had been no rainfall for several weeks previously. Corresponding to this rise in water-table was the appearance of a white or yellow efflorescence on the peat surface about 0.5-1 m outside the advancing edge of the water surface. This efflorescence dissolved completely in 10 cc distilled water and gave pH 3.2 and 12000 ppm TDS. The efflorescence is assumed to be a soluble organic salt derived from peat together with inorganic salts.

Water samples in swamps 1, A and B were taken at time of highest water level (August) and averaged pH 4.4 and 200 ppm TDS.

Typical Soil Profiles

Top of dunes

0-50 cm non-pedal, structureless, poorly coherent, excessively drained, white, sand with ca. 5% organic dust and numerous fine plant roots. Average pH March 4.0, July 3.7.

50-200 cm as for 0-50 cm horizon above but organic dust and plant roots virtually absent. Average pH March 3.8, July 3.7. Average TDS March 20 ppm.

Slopes and flats

0-5 cm as for 5-200 cm sample but with ca. 5-10% organic dust and some plant roots.

5-200 cm non-pedal, structureless, poorly coherent, well to excessively drained, white, sand with organic dust virtually absent but some plant roots. Average pH 30 cm March 4.1, July 3.7, 150 cm March 4.2, July 3.7. Average TDS March 150 cm 30 ppm.

Pultenaea reticulata band

0-1 cm as for 20-200 cm horizon.

2-20 cm as for 20-200 cm horizon with traces of peat and some decomposing litter. This horizon may represent a period of exceptionally high water-table and temporary inundation of this ecotonal band.

20-200 cm slightly pedal, slightly structure, moderately coherent, well drained, white, sand with ca. 10% organic dust and numerous fine plant roots. Average pH 30 cm March 3.8, July 3.5, 100 cm March 3.3, July 3.0 Average TDS March 100 cm 60 ppm.

Astartea fascicularis band

0-4 cm white sand with ca. 5% organic dust.

5-10 cm white sand with decomposed litter and traces of peat.

10-14 cm slightly pedal, structured (finely layered), moderately coherent, well to poorly drained, white sand with ca. 20-25% peaty dust and particles to 2 mm.

14-15 cm as for 5-10 cm horizon with slightly less organic matter. This horizon may represent a period of high water-table preceding that (and slightly less high) indicated in 2-20 cm horizon of *Pultenaea reticulata* band above.

15-35 cm pedal, structureless, coherent, poorly drained, fibrous peat with some sand. Average pH 25 cm March 3.8, July 3.9 Average TDS March 25 cm 90 ppm.

35-200 cm highly pedal, slightly structured, finely layered, very coherent, poorly drained, indurated fibrous dark brown peat. Average pH 100 cm sample March 4.0, July 3.9. Average TDS March 100 cm 90 ppm.

Melaleuca parviflora band

0-35 cm pedal, structureless, very coherent, non-fibrous, black peat. Poorly drained (very damp, March). Average pH 25 cm March 4.9, July 4.5.

40-50 cm pedal, structureless, very coherent, sand with very high peat content. Soil wet. Average pH 50 cm March 5.2, July 4.9. Average TDS March 180 ppm.

50 cm onwards saturated.

Centre of Swamp

0-5 black peat as for 18 cm onwards.

6-18 cm white flocculent material, probably ash from burnt peat.

18-100 cm highly pedal, structureless, very coherent greasy, non-fibrous, black, peat. Very poorly drained, very wet. Average pH 50 cm March 5.0, July 4.8. Average TDS March 200 ppm.

102 cm onwards, below water-table.

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